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**METHOD, APPARATUS, AND PROGRAM FOR INTELLIGENT VOLUME  
CONTROL**

**BACKGROUND OF THE INVENTION**

**1. Technical Field:**

The present invention relates to data processing and, in particular, to audio playback control. Still more particularly, the present invention provides a method, apparatus, and program for intelligent volume control in an audio system.

**2. Description of Related Art:**

Audio systems are used in a variety of environments, such as within homes, in automobiles, on boats, etc. In most environments, the interior and/or exterior conditions may result in audio interference. For example, in a home with several family members, children may cry, dogs may bark, the phone may ring, or someone may run a vacuum cleaner. In these cases, a person listening to an audio system may have to repeatedly adjust the volume up and down to remain at a desired level relative to environmental noise and interference. As another example, in an automobile the environmental noise level may increase due to road noise when it is raining or engine noise when driving at a greater speed.

Volume control systems exist which adjust the volume level according to the speed of an automobile. However, these systems have one input parameter and only one fixed

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output for each value of the one input parameter. The factory settings for such a volume control system may not be sufficient or desirable for every user. Thus, the listener may still need to adjust the volume up and down to a desirable level based upon actual conditions.

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### **SUMMARY OF THE INVENTION**

The present invention provides intelligent volume control for an audio system that adjusts a volume level based on several input parameters. The input parameters may vary depending upon the environment of the audio system. The listener may manually set a volume to a desired level relative to environmental noise and interference. The volume level and input parameters are stored as a data point. As values for the input parameters change, the volume control performs statistical analysis on the stored data point to predict a desired volume level. The audio system then adjusts the volume to the predicted level. The listener may then override the volume level and set another data point. Thus, the volume control of the present invention learns from the volume levels set by the listener and the values of the input parameters.

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### **BRIEF DESCRIPTION OF THE DRAWINGS**

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

**Figure 1** is a block diagram of a data processing system in which the present invention may be implemented;

**Figure 2** is a block diagram of an audio system in accordance with a preferred embodiment of the present invention;

**Figure 3** is a block diagram illustrating a volume prediction mechanism in accordance with a preferred embodiment of the present invention;

**Figures 4A-4D** depict example data points for volume levels in accordance with a preferred embodiment of the present invention;

**Figure 5** is a flowchart illustrating the operation of storing a data point responsive to a user manually setting the volume level in accordance with a preferred embodiment of the present invention;

**Figure 6** is a flowchart illustrating the operation of an intelligent volume control mechanism in accordance with a preferred embodiment of the present invention;

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**Figure 7** is a flowchart illustrating the operation of a volume level prediction module in accordance with a preferred embodiment of the present invention.

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#### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

With reference now to the figures and in particular with reference to **Figure 1**, a block diagram of a data processing system is shown in which the present invention may be implemented. Data processing system **100** is an example of a computer in which code or instructions implementing the processes of the present invention may be located. Data processing system **100** may be employed as an audio system for playing audio media. For example, the data processing system may be used to play compact disks or MP3 audio files.

Data processing system **100** employs a peripheral component interconnect (PCI) local bus architecture. Although the depicted example employs a PCI bus, other bus architectures such as Accelerated Graphics Port (AGP) and Industry Standard Architecture (ISA) may be used. Processor **102** and main memory **104** are connected to PCI local bus **106** through PCI bridge **108**. PCI bridge **108** also may include an integrated memory controller and cache memory for processor **102**. Additional connections to PCI local bus **106** may be made through direct component interconnection or through add-in boards.

In the depicted example, local area network (LAN) adapter **110**, small computer system interface SCSI host bus adapter **112**, and expansion bus interface **114** are connected to PCI local bus **106** by direct component connection. In contrast, audio adapter **116**, graphics adapter **118**, and audio/video adapter **119** are connected to PCI local bus **106**

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by add-in boards inserted into expansion slots. Expansion bus interface **114** provides a connection for a keyboard and mouse adapter **120**, modem **122**, and additional memory **124**. SCSI host bus adapter **112** provides a connection for hard disk drive **126**, tape drive **128**, and CD-ROM drive **130**. Typical PCI local bus implementations will support three or four PCI expansion slots or add-in connectors.

An operating system runs on processor **102** and is used to coordinate and provide control of various components within data processing system **100** in **Figure 1**. The operating system may be a commercially available operating system such as Windows XP, which is available from Microsoft Corporation. An object oriented programming system such as Java may run in conjunction with the operating system and provides calls to the operating system from Java programs or applications executing on data processing system **100**. "Java" is a trademark of Sun Microsystems, Inc. Instructions for the operating system, the object-oriented programming system, and applications or programs are located on storage devices, such as hard disk drive **126**, and may be loaded into main memory **104** for execution by processor **102**.

Audio may be played through audio adapter **116**. The user may control the playback through a user interface via graphics adapter **118** and keyboard and mouse adapter **120**. In accordance with a preferred embodiment of the present invention, data processing system **100** includes an intelligent volume control that adjusts a volume level based on input parameters. The input parameters may vary

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depending upon the environment of the audio system. For example, if the data processing system is located in a user's bedroom, the data processing system may receive input from a sensor that measures a noise level. Therefore, if environmental noise increases due to people outside the room talking or a person using a vacuum cleaner, the volume control will adjust the volume accordingly.

The listener may manually set a volume to a desired level relative to environmental noise and interference. The volume level and input parameters are stored as a data point. As values for the input parameters change, the volume control performs statistical analysis on the stored data point to predict a desired volume level. The audio system then adjusts the volume to the predicted level. The listener may then override the volume level and set another data point. Thus, the volume control of the present invention learns from the volume levels set by the listener and the values of the input parameters.

Those of ordinary skill in the art will appreciate that the hardware in **Figure 1** may vary depending on the implementation. Other internal hardware or peripheral devices, such as flash read-only memory (ROM), equivalent nonvolatile memory, or optical disk drives and the like, may be used in addition to or in place of the hardware depicted in **Figure 1**. Also, the processes of the present invention may be applied to a multiprocessor data processing system.



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For example, data processing system **100**, if optionally configured as a network computer, may not include SCSI host bus adapter **112**, hard disk drive **126**, tape drive **128**, and CD-ROM **130**. In that case, the computer, to be properly called a client computer, includes some type of network communication interface, such as LAN adapter **110**, modem **122**, or the like. As another example, data processing system **100** may be a stand-alone system configured to be bootable without relying on some type of network communication interface, whether or not data processing system **100** comprises some type of network communication interface. As a further example, data processing system **100** may be a personal digital assistant (PDA), which is configured with ROM and/or flash ROM to provide non-volatile memory for storing operating system files and/or user-generated data.

The depicted example in **Figure 1** and above-described examples are not meant to imply architectural limitations. For example, data processing system **100** also may be a notebook computer or hand held computer in addition to taking the form of a PDA. Data processing system **100** also may be a kiosk or a Web appliance.

The processes of the present invention are performed by processor **102** using computer implemented instructions, which may be located in a memory such as, for example, main memory **104**, memory **124**, or in one or more peripheral devices **126-130**.

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With reference now to **Figure 2**, a block diagram of an audio system is depicted in accordance with a preferred embodiment of the present invention. Audio system **200** may be located in a vehicle, such as an automobile, truck, or boat. Audio system **200** includes central processing unit (CPU) **202**, which may be an embedded processor or processor, such as a Pentium processor from Intel Corporation. "Pentium" is a trademark of Intel Corporation. Audio system **200** also includes memory **204**, which may take the form of random access memory (RAM) and/or read only memory (ROM).

Audio system **200** includes preamplifier **206**, which provides audio output to amplifier **230**. Audio is presented to the listener via speakers **232**, **234**. Although two speakers are shown in **Figure 2**, more or fewer speakers may be included depending upon the implementation. In many automobile stereo systems, four, five, six, or even seven speakers are typically used.

Interface adapter **208** receives input from and presents display output to interface **220**. Audio system **200** receives audio input from, for example, AM/FM tuner **212** and tape and/or CD player **214**. Other audio input may also be used, such as, for example, streaming Internet radio, digital video disk (DVD) audio, or satellite radio. Audio system **200**, under control of CPU **202**, operates the functions of the tuner, the tape player, and/or the CD player according to user interaction with the interface.

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Interface **220** includes display **221**, buttons **222**, volume control knob **223**, and tuner knob **224**. Volume level may be adjusted in preamplifier **206**. by manipulating volume control knob **223**. Manipulation of tuner knob **224** results in tuner **212** changing radio stations. More or fewer buttons and/or knobs may be included within interface **220** depending upon the implementation. For example, volume and/or tuner control may be performed digitally through buttons, sliders, or a touch screen. Audio system **200** may alternatively include voice control functionality or steering wheel mounted controls.

Audio system **200** also includes a storage device unit **216**. The storage unit may contain one or more storage devices, such as, for example, a hard disk drive, a flash memory, a DVD drive, or a floppy disk. Audio system **200** also includes an input/output (I/O) unit **218**, which provides connections to various I/O devices. Several sensors **244**, **246**, **248** are connected to I/O unit **218**. These sensors may include sensors that detect speed, whether a window is open or closed, interior or exterior noise levels, whether a convertible top is up or down, windshield wiper use and/or level, whether the headlights are on, global positioning system (GPS) coordinates, etc. In other words, almost any condition or parameter in, about, or around an automobile may be detected through the use of sensors **244**, **246**, **248**.

In accordance with a preferred embodiment of the present invention, audio system **200** includes an

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intelligent volume control function that adjusts a volume level based on input parameters. The input parameters may be received from sensors **244**, **246**, **248**. The listener may manually set a volume to a desired level relative to environmental noise and interference. "Learn" button **225** may be provided on interface **220**. This button may be selected by the listener when the listener wishes to have the audio system learn the volume level with respect to the input parameters.

The volume level and input parameters are stored as a data point. CPU **202** may sample the values of sensors **244-248** via I/O unit **218** periodically, such as, for example, every second. As values for the input parameters change, the volume control performs statistical analysis on the stored data point to predict a desired volume level. The audio system then adjusts the volume to the predicted level. The listener may then override the volume level and set another data point by selecting button **225**. Thus, the volume control of the present invention learns from the volume levels set by the listener and the values of the input parameters.

The intelligent volume control mechanism of the present invention may also be used to adjust other audio output parameters, such as balance, fade, bass, treble, or equalizer settings. For example, if a window is open on the passenger's side of an automobile, the balance may be adjusted to increase the volume on that side. If the windows are open in the back of an automobile, the fade

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may be adjusted to increase the volume in the rear speakers.

**Figure 3** is a block diagram illustrating a volume prediction mechanism in accordance with a preferred embodiment of the present invention. Volume prediction module **310** receives input parameters **302**. In the depicted example, the input parameters include speed, noise level, window open/closed, and audio type. Audio type may be received from an audio medium, such as a compact disk, MP3 file, or radio station. For example, a listener may be listening to rock music on a CD, a talk radio station, or a comedy show on MP3.

When a value of one of input parameters **302** changes, volume prediction module **310** receives data points **304** from storage. Data points **304** are historical data points consisting of a volume level associated with a set of input parameter values. The data points may be time stamped and stored in a persistent storage, such as, for example, a database. Data points **304** may be selected based on input parameters **302**. For example, if the windows are open, prediction module **310** may rule out any data points for which the windows were closed. The prediction module may also consider only data points for which a parameter is within an acceptable proximity to the corresponding input parameter. For example, if the speed input parameter is 55 miles per hour (MPH), then the prediction module may consider only data points for which the speed is 50-60 MPH.

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The volume prediction module then performs statistical analysis to determine volume prediction **312**. For example, if ten data points exist with the exact same input parameter values, the volume prediction module may take an average of the five most recently set volume levels. The volume prediction module may also remove outliers, perform curve fitting, perform linear extrapolation, perform linear regression analysis, perform multiple regression analysis, and perform other data mining and statistical analysis techniques commonly known in the industry.

Outliers are data points that deviate from expected values or the statistical trend of the other data points. Outliers may skew results of statistical analysis and are preferably removed.

Regression is a functional relationship between two or more correlated variables that is often empirically determined from data and is used especially to predict values of one variable when given values of the others. Linear regression (or any other regression) seeks to find the equation of the line (or curve) that best fits the data set. Therefore, curve fitting may employ linear regression (for a line, which is a special case of a curve) or non-linear regression (for a curve) to determine a "best fit" curve given the data points. From this "best fit," the data points may be extrapolated to find values, given variables for which a data point does not exist.

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Multiple regression is a statistical technique which allows one to examine the relationship between two or more predictor variables (PVs) and a criterion variable (CV). Simple linear regression is limited to a single predictor variable. Predictor variables (a.k.a. independent variables) are variables one manipulates or has some control over. Criterion variables (a.k.a. dependent variables) are variables one measures during an experiment. Specifically, when the criterion variable is studied as a function of the predictor variables, multiple regression analysis may be employed. Multiple regression allows one to determine a linear relationship between variables that can be used in prediction.

Volume prediction **312** may be stored as a data point, which identifies the predicted volume level with respect to a given set of parameters. For example, volume prediction **312** may be a number between 0 and 10, where 10 is the loudest, although the numerical range convention may vary depending upon the implementation. The volume prediction module **310** may continuously fill in data points even when the audio system is not producing audio output. In other words, whenever sensor data is sampled, the volume prediction module may generate a prediction, which may be stored as a data point as if the user deliberately set the value. These data points may be identified as predictions using, for example, a flag or Boolean variable to distinguish these points from data points actually set by the user. Prediction data points may be overridden with manually selected volume level

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data points and may be recalculated as input variables change. The volume may then be adjusted in real time by retrieving a data point that is closest to the input parameters. Alternatively, volume prediction **312** may be used to adjust the volume of the audio system on the fly.

Audio type may simply include categories of audio, such as 80's, 90's, rock, classical, jazz, talk, etc. Alternatively, audio type may identify a particular CD, song, show, or commercial. A listener may listen to an entire CD and increase the volume only for a particular song on the CD. A data point may be saved for each song and, thus, volume prediction module **310** may predict a new volume level responsive to a change in song, even if the CD or radio station does not change. Furthermore, the volume prediction will be based on input parameters **302**; therefore, the volume will be adjusted to take into account the environmental noise or interference.

A song may be identified in a table of contents on a CD or through a look-up mechanism. CD look-up mechanisms, such as Cddb, Gracenote, and FreeDB, are commonly known in the computer media player industry. Also, digital radio, such as satellite radio or Internet radio, may include identification and category information. MP3 files typically include song, artist, and category information in an embedded tag file. Therefore, this information may be provided by the media source itself, rather than a sensor.

In an alternative embodiment, data points may be stored for a plurality of users. Users may be



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identified, for example, when a particular driver uses a keychain remote to unlock or start the car. Many automobiles use an identifier in the keychain remote to identify the driver. The listener may also be identified by selecting a seat position preset button, by voice identification, or other identification techniques known in the art. The volume prediction module may then predict preferred volume levels on a user-by-user basis.

**Figures 4A-4D** depict example data points for volume levels in accordance with a preferred embodiment of the present invention. As shown in **Figure 4A**, a data point may include a date/time, speed, noise level, window status, audio type, and volume level. In the example shown in **Figure 4A**, the automobile was traveling 51 MPH, the external noise level had a value of 25, the windows were closed, the user was listening to talk radio, and the volume was set at 6.5. Noise levels and volume levels may be in any scale. Typically volume levels are on a scale of zero to ten; however, any convention may be used.

As another example, **Figure 4B** shows a data point for which the automobile was traveling 26 MPH, the external noise level had a value of 20, the windows were closed, the user was listening to rock music, and the volume was set at 7.0. Clearly, the listener prefers to listen to rock music at a higher volume level, especially considering the lower speed and lower external noise level.

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As shown in **Figure 4C**, the speed increased to 60 MPH and the noise level increased to a value of 40. The listener was still listening to rock music with the windows closed. However, the listener increased the volume to 9.0. Based upon these data points, it is clear that the listener prefers to significantly increase the volume at higher speeds and resulting higher external noise levels. As shown in **Figure 4D**, the speed decreased to 54 MPH and the noise level decreased to a value of 38. The volume is decreased to 8.5.

Suppose input parameters are received such that the speed then increases to 55 MPH. Given these data points, the intelligent volume control mechanism of the present invention may perform an average of the closest data points, shown in **Figures 4C** and **4D**, to predict a volume level of 8.75. Alternatively, the intelligent volume control mechanism may perform curve fitting to predict a volume level of 8.6.

With reference now to **Figure 5**, a flowchart is shown illustrating the operation of storing a data point responsive to a user manually setting the volume level in accordance with a preferred embodiment of the present invention. The process begins and receives user input setting the volume level (step **502**) and adjusts the volume according to the user input (step **504**). Then, the process obtains input parameters (step **506**) and stores the volume setting and input parameters as a data point in data storage (step **508**). Thereafter, the process ends.

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Turning now to **Figure 6**, a flowchart illustrating the operation of an intelligent volume control mechanism is shown in accordance with a preferred embodiment of the present invention. The process begins and obtains input parameters (step **602**). The process then obtains a prediction for the volume setting using the input parameters (step **604**). The process may obtain a prediction by retrieving a closest data point based on the input parameters or, alternatively, may perform statistical analysis on data points on the fly to determine a volume prediction.

The process adjusts the volume using the volume prediction (step **606**). Next, a determination is made as to whether an exit condition exists (step **608**). An exit condition may exist, for example, when the audio system is turned off or when a user turns off the intelligent volume control mechanism. If an exit condition exists, the process ends. Otherwise, the process returns to step **602** to obtain input parameters.

Next, with reference to **Figure 7**, a flowchart is shown illustrating the operation of a volume level prediction module in accordance with a preferred embodiment of the present invention. The process begins and obtains input parameters (step **702**). A determination is made as to whether one or more input parameters have changed (step **704**). If input parameters have changed, the process obtains data points from data storage (step **706**) and performs analysis on the data points to generate a volume prediction (step **708**).

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Next, the process stores the prediction in data storage as a data point (step **710**) and a determination is made as to whether an exit condition exists (step **712**). An exit condition may exist, for example, when the volume level prediction module is turned off. If an exit condition exists, the process ends. Otherwise, the process returns to step **702** to obtain input parameters. Returning to step **704**, if input parameters have not changed, the process continues to step **712** to determine whether an exit condition exists.

Thus, the present invention solves the disadvantages of the prior art by providing an intelligent volume control for an audio system that adjusts a volume level based on several input parameters. The input parameters may vary depending upon the environment of the audio system. As values for the input parameters change, the volume control performs statistical analysis on data points to predict a desired volume level. The audio system then adjusts the volume to the predicted level.

Thus, the volume control of the present invention learns from the volume levels set by the listener and the values of the input parameters. As the volume control learns the preferred volume levels of the listener, the listener needs to adjust the volume manually on fewer and fewer occasions. The listener may then use the audio system in a vehicle, for example, and concentrate on driving, rather than on repeatedly adjusting the volume to counteract environmental noise.

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It is important to note that while the present invention has been described in the context of a fully functioning data processing system, those of ordinary skill in the art will appreciate that the processes of the present invention are capable of being distributed in the form of a computer readable medium of instructions and a variety of forms and that the present invention applies equally regardless of the particular type of signal bearing media actually used to carry out the distribution. Examples of computer readable media include recordable-type media such a floppy disc, a hard disk drive, a RAM, and CD-ROMs and transmission-type media such as digital and analog communications links.

The description of the present invention has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. The embodiment was chosen and described in order to best explain the principles of the invention, the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.